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GAS POWERED VEHICLE EVALUATION PROGRAM

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TRANSPORT CANADA

ROAD SAFETY BRANCH

by

T E S Limited

Ottawa, Canada

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1. INTRODUCTION

The purpose of this program was to demonstrate and evaluate the performance and safety of alternative fuels in motor vehicle applications.

Increased vehicle manufacturer interest in selling vehicles powered by alternative fuels resulted in the publishing of proposed Canada Motor Vehicle Safety Standards covering equipment, installation and crash-worthiness of Liquified Propane Gas (LPG) and Compressed Natural Gas (CNG) fuel systems. These standards were proposed in the Canada Gazette, Part I on 2 January 1982, with a proposed effective date of 1 September 1982. This program was part of a standards development project designed to ensure that the safety of gaseous fuel systems be equivalent to or better than that of gasoline and diesel fuel systems. The increased demand for gaseous fuel-powered vehicles has resulted from the overall awareness of the need for reduced consumption of oil in Canada, emphasized by the National Energy Program.

Twelve 1981 vehicles were used in the evaluation program. Four different makes including three Chevrolet Impalas, three Dodge Ram Custom 150 pick-up trucks, three Ford Econoline 100 vans and three Oldsmobile Omegas were tested. Within each make, one vehicle remained stock, running on gasoline, one vehicle was converted to run on propane and one vehicle was converted to run on either CNG or gasoline (switch selectable).

The tests performed included emissions, fuel consumption, performance, driveability, cold starting, 50 mph rear end collisions, inflammability and a refuelling evaluation. Table 1 identifies the vehicles and summarizes the tests performed on each vehicle. The emissions and fuel consumption tests were performed by the Department of Environment in Ottawa, Ontario. All remaining tests were performed at Transport Canada's Motor Vehicle Test Centre in Blainville, Quebec.

T E S Limited carried out the performance, driveability, cold starting and refuelling evaluation. The Test Centre staff conducted the rear end collisions and inflammability tests under the supervision of T E S Limited.

TABLE 1

VEHICLE IDENTIFICATION

and

TESTS PERFORMED

VEHICLE IDENTIFICATION					TESTS PERFORMED					
Vehicle Test No	Make and Model	Body Style	VIN	Powered By	Emissions & Fuel Consumption	Performance	Driveability	Cold Starting	Crash	Fire
8	1981 Chevrolet Impala	4 dr.	2G1AL69J5B1101058	Gasoline	X	X	X	–	–	–
9	1981 Chevrolet Impala	4 dr.	2G1AL69JOB1101114	Propane	X	X	X	–	–	–
1	1981 Chevrolet Impala	4 dr.	2G1AL69JOB1101582	CNG	X	X	X	–	–	–
3	1981 Dodge Ram Custom 150	Pickup	1B7FD14R6B5106845	Gasoline	X	X	X	–	–	X
11	1981 Dodge Ram Custom 150	Pickup	1B7GD14R3B5105849	Propane	X	X	X	–	–	X
2	1981 Dodge Ram Custom 150	Pickup	1B7GD14R2B5117281	CNG	X	X	X	–	–	X
5	1981 Ford Econoline 100	Van	2FTDE04F4BBA10579	Gasoline	X	X	X	X	X	–
12	1981 Ford Econoline 100	Van	2FTDE04POBBA10580	Propane	X	X	X	X	X	–
6	1981 Ford Econoline 100	Van	2FTDE04F2BBA10581	CNG	X	X	X	X	X	–
7	1981 Oldsmobile Omega	4 dr.	1G3AB69X2BW151522	Gasoline	X	X	X	–	X	–
10	1981 Oldsmobile Omega	4 dr.	1G3AB69X8BW151699	Propane	X	X	X	–	X	–
4	1981 Oldsmobile Omega	4 dr.	1G3AB69X6BW121388	CNG	X	X	X	–	X	–

2. FILMING

All major aspects of this program have been fully documented on film under the planning and supervision of T E S Limited. The filming is such that each or any major segment of the test program can be made into a self explanatory film clip, or an overall film of the entire program may be produced.

The majority of the footage, in 16 mm colour, was shot and produced by SDA Productions, Montreal, under contract to the National Film Board. High speed black and white footage of the crash tests was shot and produced by Transport Canada's Motor Vehicle Test Centre staff.

3. EMISSION TESTS

Preliminary results of the emissions tests are presented in Appendix A. An indepth analysis of these results will be produced under separate cover by the Air Pollution Control Directorate, Engineering Assessment Branch, Department of Environment.

4. PERFORMANCE

A series of standing start accelerations, passing speed accelerations and top speed runs were scheduled as performance tests.

All twelve vehicles were tested for performance in both the unloaded mode (vehicle with fuel, driver, operator and instrumentation) and the gross vehicle weight rating (GVWR) mode. Individual wheel scales were used to measure the testing weight. The GVWR for a vehicle was taken from the vehicle's data label. The vehicle was then loaded with sand bags to the appropriate GVWR, with the weight distributed over each axle as prescribed.

For testing performance, a Nucleus Digital 5th wheel was used. Before testing, a vehicle was warmed up by driving it at least 5 laps (or over 20 miles) around the low speed track.

Acceleration tests were done several times and in both directions of the track to minimize errors and negate wind effect. For a 0-60 mph test, the driver would bring the vehicle to rest, while the operator would reset the 5th wheel timer. The driver would then proceed with a full throttle acceleration until the velocity would indicate 60 mph. At this point, the operator would stop the timer and record the acceleration time.

A similar routine was used for the 50-70 mph passing speed tests. However, this time, the driver would maintain a steady speed of 50 mph and would signal the operator when he was to accelerate. The operator would then start the timer. When a speed of 70 mph was reached, the operator would stop the timer and record the passing speed time.

The procedure outlined above was carried out on every vehicle in the GVWR mode and the unloaded mode.

Table 2 presents the results of the performance tests. Comparing the results in the table, one notices a definite trend within a group; in general the gasoline powered vehicle performed better than the propane powered vehicle, which in turn performed better than its CNG counterpart. However, there are a few exceptions to this trend and they can be noticed in Table 2. A rating system was established, awarding 3 points to the top performer in a group from a certain category, 2 points for the second in the group and 1 for the last. The results are as follows:

Gasoline	45 points
LPG	35 points
CNG	16 points

Top speed tests were not possible due to the closing of the Test Centre's high speed track for climatic reasons.

TABLE 2

PERFORMANCE TEST RESULT SUMMARY

Vehicle Test No.	Make and Model	Powered By	Engine Displacement (L)	Acceleration Tests					
				Unloaded			Loaded to GVWR		
				Test Weight (lb.)	0-60 mph (sec.)	50-70 mph (sec.)	Test Weight (lb.)	0-60 mph (sec.)	50-70 mph (sec.)
8	Chevrolet Impala	Gasoline	4.4	4145	13.0	10.6	4828	18.8	15.1
9	Chevrolet Impala	Propane	4.4	4330	17.7	12.3	4828	21.1	14.8
1	Chevrolet Impala	CNG	4.4	4310	23.5	18.1	4828	25.4	21.6
3	Dodge Ram	Gasoline	5.2	4190	11.8	8.0	5500	15.6	10.8
11	Dodge Ram	Propane	5.2	4430	14.2	10.6	5500	17.2	12.6
2	Dodge Ram	CNG	5.2	4300	18.3	14.1	5500	24.7	22.8
5	Ford Econoline	Gasoline	5.0	4025	14.2	10.6	5600	20.4	14.8
12	Ford Econoline	Propane	5.0	4320	15.3	10.9	5600	19.9	14.3
6	Ford Econoline	CNG	5.0	4250	23.6	20.0	5600	30.4	32.9
7	Oldsmobile Omega	Gasoline	2.8	2805	13.4	9.5	3570	16.1	12.4
10	Oldsmobile Omega	Propane	2.8	3085	14.4	9.8	3570	17.7	14.2
4	Oldsmobile Omega	CNG	2.8	3090	21.9	19.9	3570	24.4	24.1

5. DRIVEABILITY

The object of the driveability tests was to assess and rate the vehicles of the same make and model against each other, comparing only their fuel systems. Thus, for example, the three Impalas were tested and were rated separately keeping in mind the type, capability and purpose of the vehicle. In other words, one was not comparing an Omega with a Dodge Ram, but rating a vehicle on its drivetrain merits as compared to another vehicle of the same group powered by a different fuel.

The evaluation of a vehicle's engine performance was based on starting capability, stalling frequency, idling qualities and driver feel.

The "SID" (Start, Idle, Drive)[1] rating system for driveability was used. Some alterations were made to the original rating system after experimenting with it. The finished driving cycle is explained in Appendix "B".

Initial familiarization runs were carried out so that the test engineer became familiar with the vehicles, procedure and rating system. Furthermore, the vehicles were run through driveability assessments twice in reverse order to give a fair rating to all vehicles.

Prior to testing, the vehicles were parked overnight by the side of the track so as to be cold for testing. A stop watch, the vehicle's odometer and speedometer were used as measuring instruments instead of a 5th wheel because of wet weather limitations. The vehicles were run through the driving cycle and starting time and number of stalls were recorded and rated according to the rating system in Appendix B.

[1] R.S. Rarey June 1975, revised with approval of Carburetor & Driveability CWRP Committee, June 1979.

Table 3 presents results of starting, stalling and drive ratings along with vehicle and atmospheric data. The appropriate scores are given with an overall unweighted average for driveability.

In general, gasoline powered vehicles performed better than propane or CNG, but only slight differences were found between gasoline and propane. CNG on the other hand was difficult to start and was noticeably inferior to gasoline and propane in many cases. Figures 1 to 4 graphically represent the average idle scores awarded during the driving cycles.

It is suggested that the performance of the CNG vehicles might be improved with further engine adjustments.

No definite relationship or pattern can be noticed between groups. This is felt to be due to different engine adjustments during conversion.

TABLE 3

DRIVEABILITY SUMMARY

Vehicle Test No	Make and Model	Powered By	Soak Time (hr.)	Weather Conditions		Driveability Ratings					Comments
				Temp (°C)	Relative Humidity (%)	Starting	Stalling	Idling	Driving	Overall Average	
8	Chevrolet Impala	Gasoline	18	Run 1 0	86	9.0	7.0	9.0	9.0	8.3	
			65	Run 2 -4	93	8.7	7.0	8.0	9.0		
9	Chevrolet Impala	Propane	18	Run 1 0	86	8.7	7.0	7.0	9.0	7.6	
			65	Run 2 -7	93	8.3	7.0	5.0	9.0		
1	Chevrolet Impala	CNG	18	Run 1 1	69	6.7	7.0	7.0	9.0	7.5	
			65	Run 2 -7	93	7.3	5.7	8.0	9.0		
3	Dodge Ram	Gasoline	17	Run 1 -1	93	9.0	7.0	7.0	5.0	7.1	-hesitation noticed during 20-30 mph accelerations
			66	Run 2 -4	93	8.7	7.0	8.0	5.0		
11	Dodge Ram	Propane	17	Run 1 -1	93	8.3	7.0	6.0	9.0	7.1	-did not idle on its own at reduced R.P.M.
			65	Run 2 -4	93	6.0	6.3	5.0	9.0		
2	Dodge Ram	CNG	17	Run 1 -1	93	5.0	5.0	4.0	7.0	4.9	-difficult to start when cold - very jerky at 30 mph cruise and in decelerations
			65	Run 2 -4	93	6.0	5.0	4.0	3.0		
5	Ford Econoline	Gasoline	22	Run 1 -4	86	9.0	7.0	8.0	7.5	7.7	
			21	Run 2 0	64	8.7	6.3	7.0	8.0		
12	Ford Econoline	Propane	22	Run 1 -4	86	9.0	7.0	7.0	9.0	7.9	
			22	Run 2 0	64	9.0	7.0	6.0	9.0		
6	Ford Econoline	CNG	23	Run 1 -4	80	5.0	4.0	5.0	4.0	5.3	-hesitation noticed when trying to maintain 30 mph -difficult to start when cold
			20	Run 2 0	69	8.3	5.3	4.0	7.0		
7	Oldsmobile Omega	Gasoline	23	Run 1 -4	80	9.0	7.0	7.0	3.0	6.3	-severe hesitate on full throttle until step 18
			22	Run 2 1	59	8.3	7.0	6.0	3.0		
10	Oldsmobile Omega	Propane	23	Run 1 -4	80	9.0	7.0	5.0	9.0	7.5	
			23	Run 2 1	59	8.7	7.0	5.0	9.0		
4	Oldsmobile Omega	CNG	16	Run 1 -2	93	8.0	6.3	7.0	9.0	7.2	-did not start on first crank on any start -slow on acceleration up to step 5
			64	Run 2 -7	93	8.7	7.0	5.0	7.0		

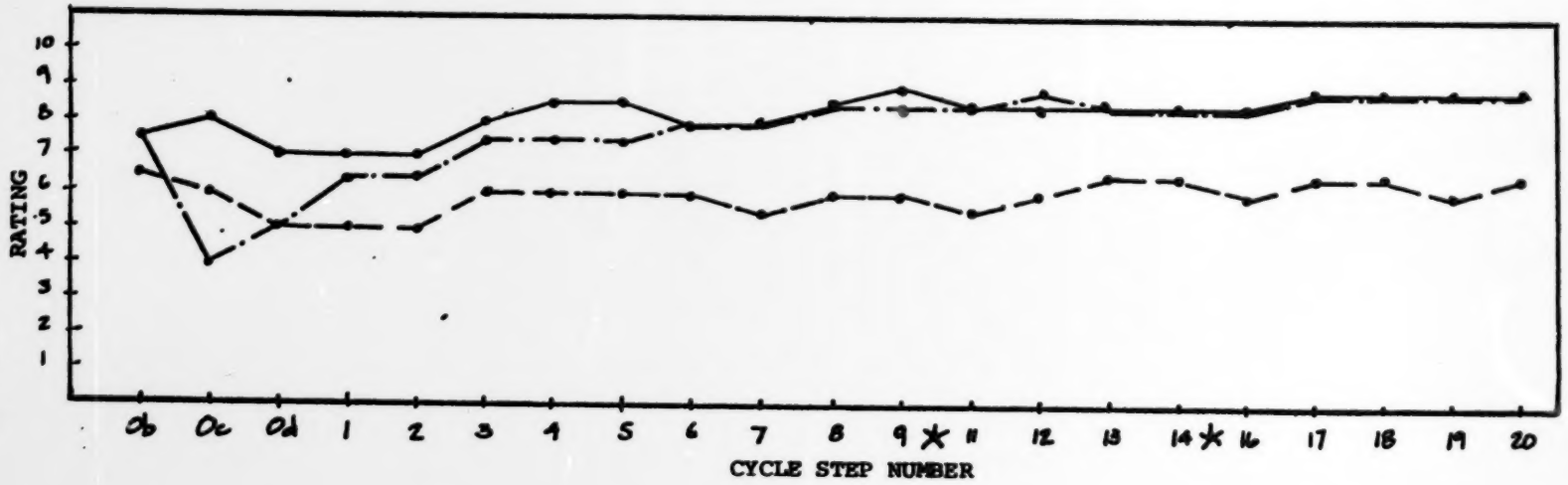


FIGURE 1

IDLE RATING - CHEVROLET IMPALA

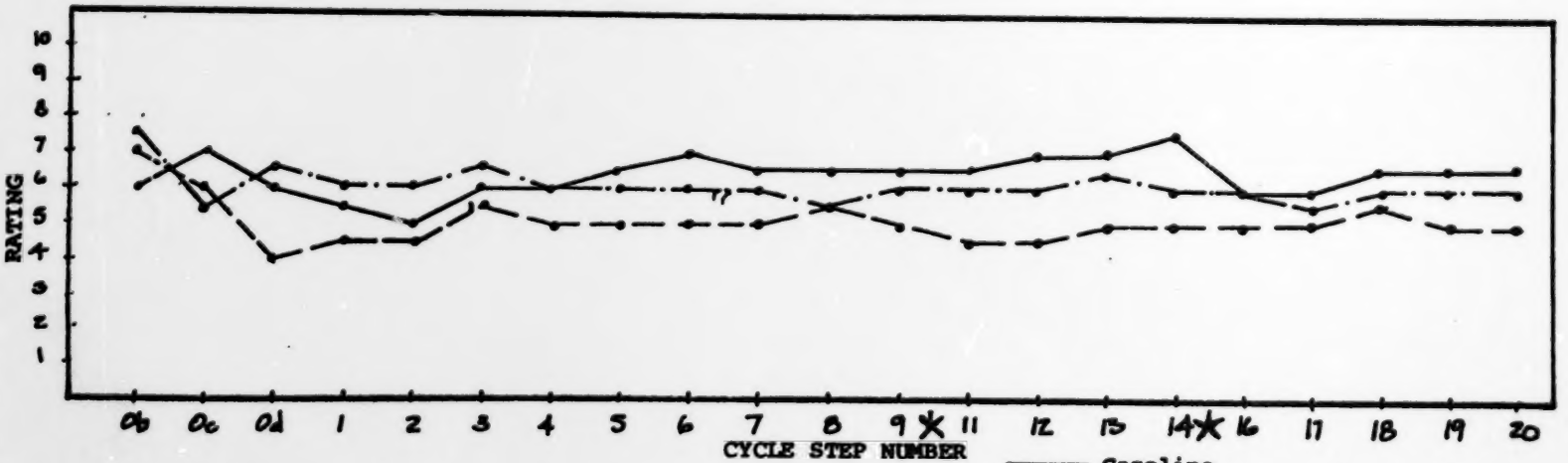


FIGURE 2

IDLE RATING - OLDSMOBILE OMEGA

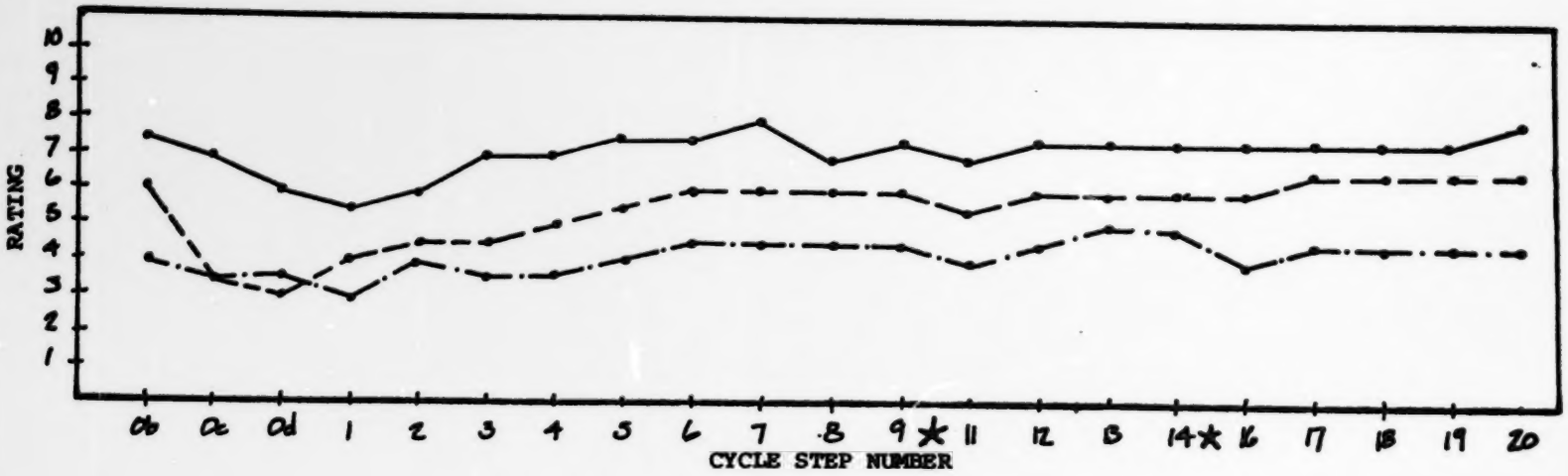


FIGURE 3

IDLE RATING - DODGE RAM

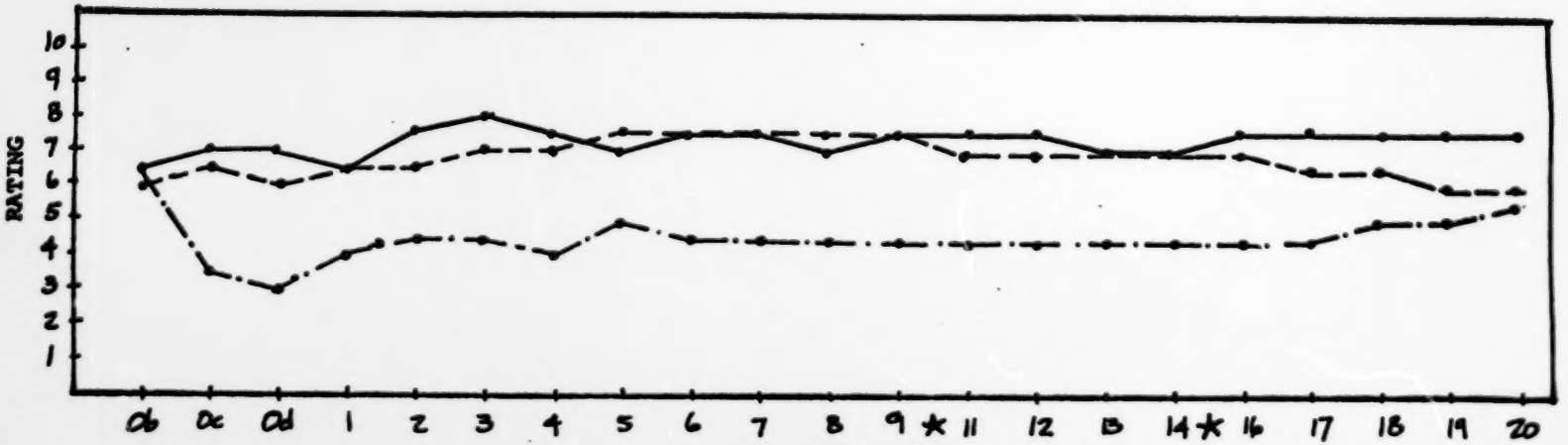


FIGURE 4

IDLE RATING - FORD ECONOLINE

6. COLD STARTS

The small cold room at Transport Canada's Motor Vehicle Test Centre was used to compare the cold starting capability of the three different fuel systems. The temperature, pressure and humidity of the cold room were monitored by an operator and were held relatively constant throughout the soaking and the starting time of the vehicles.

Three Ford Econoline 100 vans, each powered by different fuels were used to illustrate the cold starting differences and similarities between conventional gasoline, propane and compressed natural gas.

A vehicle was driven into the cold room and was allowed to soak at the predetermined temperature overnight. The soaking time of the vehicles ranged from 14 to 21 hours, which is in excess of the recommended time for vehicle temperature stabilization (see SAE J1253).

The optimum testing temperature was one at which the vehicles would start, but where it would be cold enough to measure the cranking time of the engine in starting attempts. A separate experiment was carried out with the gasoline powered Chevrolet and the optimum temperature was found to be around the -25°C mark.

After the vehicle was in the cold room the hood was raised to allow for air circulation around the engine. The oil dip stick was removed from the vehicle and was replaced by a thermocouple dip stick.

With this arrangement, the oil temperature could be monitored until stabilization.

Before attempting to start a vehicle, the conditions inside the cold room were recorded along with the engine oil temperature. Proper care was taken to install an exhaust hose over the vehicle's exhaust pipe and the exhaust fans were started.

Once the necessary preparation had been carried out, the vehicle was started according to the manufacturers recommendations. The starting procedures as outlined in the following test results of Table 4, along with cranking time, atmospheric and cold room conditions and comments were all recorded.

The comments are self-explanatory and conclusive of the cold starts, however, a generalization cannot be made due to the limited scope of the present program.

TABLE 4

COLD START SUMMARY

Test Vehicle #	Make and Model	Powered By	Cold Room Temp. (^{o}C)	Cold Room Press. (mm H_2O)	Cold Room Dew Pt. (^{o}C)	Soak Time (hr.)	Oil Temp. (^{o}C)	Crank Time (sec.)	Starting Procedure	Comments
12	Ford Econoline 100	Propane	-25	+3	-23	14	-25.7	8	turn the ignition key on, depressed pedal slowly, all the way down and let go, turn the ignition key to the cranking position.	-no problems starting, ran smoothly for over a minute, stopped when trying to let it idle on its own, could not get it started again.
5	Ford Econoline 100	Gasoline	-25	+4	-28	21	-25.4	13	same as above	-some hesitation in cranking, but once starting kept running and could idle by itself.
6	Ford Econoline 100	CNG	-25	+4	-28	16	-25.4	15 (die out), 4 (die out), 1(start)	depressed primer four times, rest same as above	-hesitation in cranking, two die outs, kept running and could idle by itself.

7. RELATIVE SAFETY OF REFUELLING

The three fuel systems all required careful attention to proper procedures for refuelling as all gave off potentially dangerous fumes.

Gasoline refuelling involves the danger of igniting the vapour as well as any spilt liquid.

Propane refuelling involves the danger of igniting vapour and liquid exiting the bleeder valve. The liquid quickly vapourizes and dissipates in an open area.

CNG refuelling involves the danger of igniting the small amount of vapour released when the drop hose is disconnected.

Conclusion:

With attention to proper procedures, none of the fuel systems was judged to be significantly more dangerous during refuelling.

8. CRASH TESTS

The purpose of the crash tests was to evaluate the relative safety of each of the fuel systems under real life conditions. The three Ford Econoline vans and the three Oldsmobile Omega sedans were each subjected to a rear end impact of approximately 50 mph by six similar 1976 Plymouth Volare "bullet" cars. The integrity of the vehicle's fuel system was evaluated after each crash.

i. Test Location

The tests were carried out at Transport Canada's Motor Vehicle Test Centre, Blainville, Quebec.

ii. Bullet Car Parameters

- gasoline tanks emptied of fuel and filled with water
- headlights on
- engine not running

iii. Test Vehicle Parameters

- engine running
- headlights on
- transmission in neutral
- windows down
- amount of fuel as specified in Table 5

iv. Test Results

Test results are presented in Table 5 and photographs 1 to 14. The gasoline and CNG vehicles did not release fuel or result in fire or explosion. Both propane fuel systems leaked fuel at a slow rate due to severed lines or snapped fittings, but vapour dissipated without fire or explosion. The tanks continued to leak until empty.

v. Conclusion

In a rear end collision, the fuel systems of the propane vehicles tested were more vulnerable to damage due to the location of their tanks. The resulting leakage did not result in fire or explosion.

TABLE 5

CRASH TEST SUMMARY

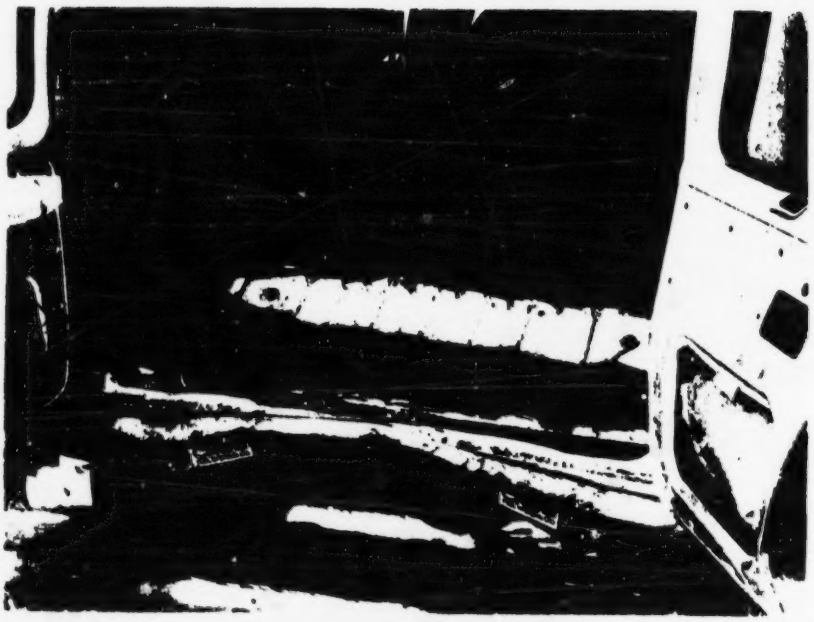
Vehicle Test No.	Model	Powered by	Amount of Fuel	No. of Tanks	Position of Tank	Bullet Car Release Speed (mph)	Description of Fuel System After Impact
5	Ford Econoline	Gasoline	Approx. 1 gal.	1	stock	50.01	-tank was not disturbed
12	Ford Econoline	Propane	full, gasoline tank removed	2	forward of and slightly below rear bumper	48.08	-fill fitting snapped off at tank resulting in the release of fuel at a slow rate -vapour dissipated with no combustion
6	Ford Econoline	CNG	850 psi, gasoline tank filled with water	2	behind driver seat on cargo floor	48.72	-tanks and supply lines were dislocated slightly, but system held pressure
7	Oldsmobile Omega	Gasoline	Approx. 1 gal.	1	stock	49.47	-tank was deformed but did not leak
10	Oldsmobile Omega	Propane	full, gasoline tank removed	1	in trunk, just behind parcel shelf	46.66	-hose to filling vent was severed resulting in the release of fuel at a slow rate -vapour dissipated with no combustion
4	Oldsmobile Omega	CNG	1100 psi gasoline tank filled with water	1	in trunk, under parcel shelf	44.66	-tank dislocated slightly but system held pressure

Photograph 1

CNG Installation - Ford Van

Photograph 2

CNG Tank Bracket - Ford Van



Photograph 3

CNG Ford Van

Photograph 4

Propane Installation - Ford Van

Photograph 5

Propane Damage - Ford Van

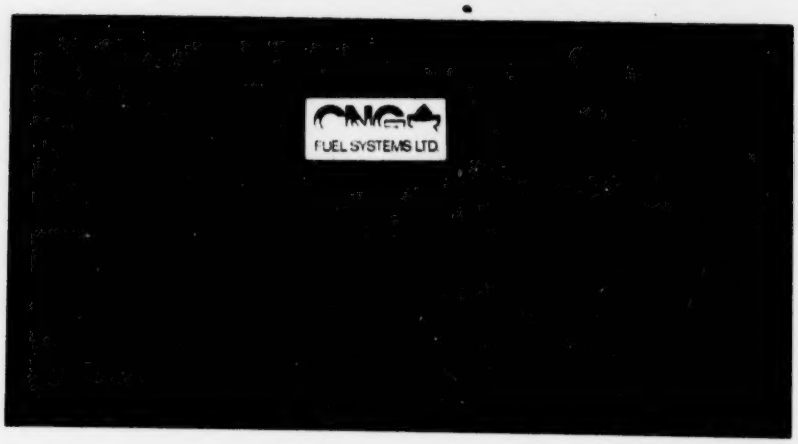
(fuel line damaged by lower edge of bumper)

Photograph 6

Gasoline Ford Van

Photograph 7

Gasoline Ford Van
(Tank Undisturbed)

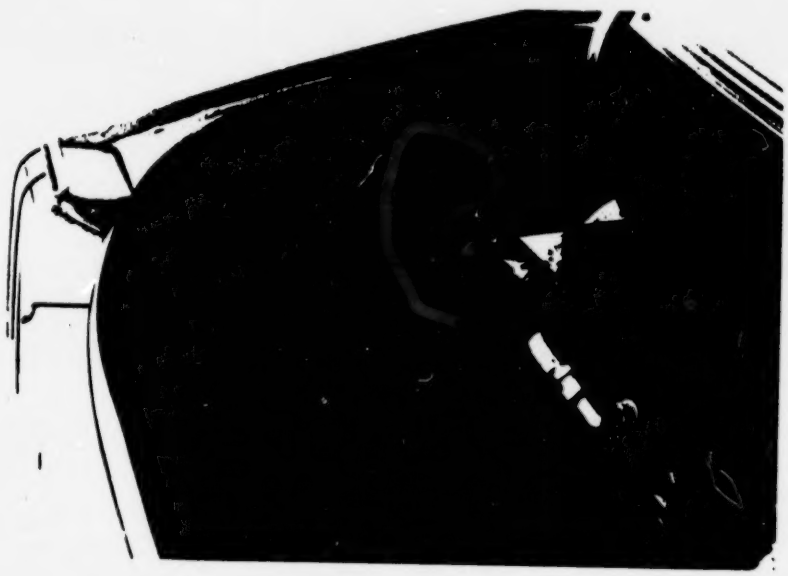


Photograph 8

CNG Installation - Oldsmobile Omega

Photograph 9

CNG Tank – Oldsmobile Omega



Photograph 10

Propane Installation - Oldsmobile Omega

Photograph 11

Propane Oldsmobile Omega

Photograph 12

Propane Damage - Oldsmobile Omega
(pinched hose on right)

Photograph 13

Gasoline Oldsmobile Omega

Photograph 14

Gasoline Tank - Oldsmobile Omega

9. FIRE TESTS

The three Dodge Ram pick-up trucks were each separately set on fire to evaluate the relative safety of each vehicle during a fire situation.

A metal pan 4' x 8' was placed under the middle of the vehicle and filled with approximately 10 gallons of gasoline. The vehicle's ignition was in the off position. A lighted flare was then dragged through the pan and the events were recorded on film and timed with a stop watch. Significant results are presented in table 6 and photographs 15 to 19.

Results

i. Gasoline
The plastic gasoline tank melted and its contents dumped into the metal pan. No explosions occurred.

ii. Compressed Natural Gas (CNG)
The vehicle was tested with a tank pressure of 1100 psi. This was the highest pressure possible from the supply tanks due to the cold climatic conditions. The gasoline tank was filled with water. No events related to the CNG fuel system were noticed during the fire. Post inspection showed that the lower casing of the fuel regulator had melted away. It is probable that the fuel burned off from this point.

iii. Liquified Propane Gas (LPG)
After 9 minutes the pressure relief valve opened for approximately 2 seconds and then closed, resulting in a short, intense flare-up. This event happened two more times and then the valve melted out. This resulted in a blow-torch like effect with bright yellow flames extending well beyond the tailgate of the truck. This condition continued at an intense rate for several minutes and slowly lessened in intensity as the fuel supply decreased. After

approximately 7 minutes, the burn rate was noticeably reduced. Rapid burning around the headliner was also noticed. This was probably due to a leak at the fuel gauge sensor. Post inspected confirmed that the pressure relief valve had melted out. Also, the propane tank and tailgate were both noticeably warped from the intense heat.

Conclusions:

Of the three fuel systems tested, the propane system produced the most intense heat, however the pressure relief valve worked properly and no explosions occurred.

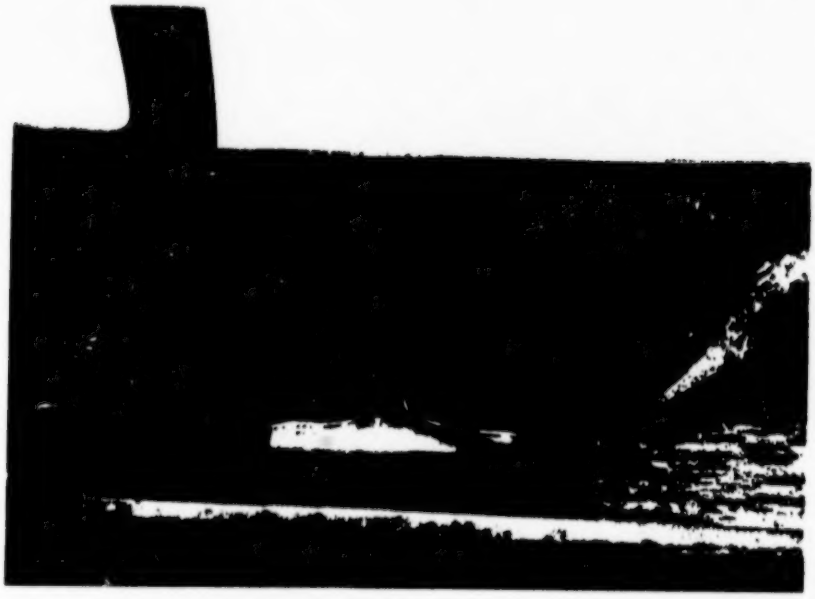
It should be noted that the CNG system may have behaved differently if the filling equipment was capable of approaching the design working pressure of 3000 psi.

Overall, no explosions occurred and the propane burned at a noticeably higher temperature than the other two fuels. In terms of relative safety, no significant differences could be made between the three fuel systems.

TABLE 6

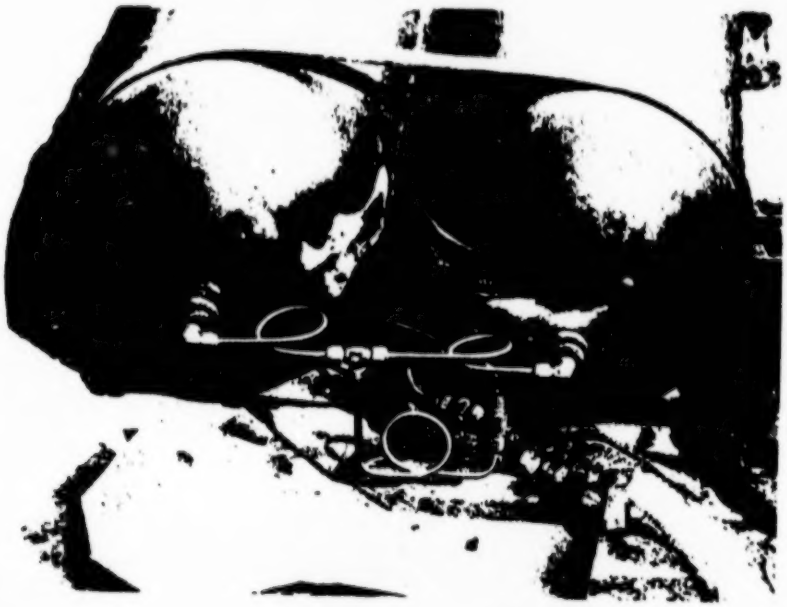
FIRE TEST SUMMARY

Vehicle Test No.	Make and Model	Powered By	Amount of Fuel	Number of Tanks	Significant Events
3	Dodge Ram	Gasoline	1/2 full	1	-plastic fuel tank melted and dumped contents into metal pan. -test deemed complete after 30 minutes
11	Dodge Ram	Propane	3/4 full	1	-pressure release valve operated after 9 minutes of burning, resulting in a short flare-up of approximately 2 seconds, directly towards the rear of the vehicle. -valve operated similarly 2 more times at 10 minutes and 11 minutes. -valve melted out at 12 minutes and flare-up continued for approximately 7 minutes. -rapid burning around the headliner, probably due to leakage at the fuel gauge sensor, was also noted. -test deemed complete after 25 minutes.
2	Dodge Ram	CNG	1100 psi (gasoline tank filled with water)	2	-no event related to the fuel system was noticed. -test deemed complete after 35 minutes. -post inspection showed that the lower casing of the fuel regulator had melted away probably resulting in the burning off of the fuel from this point.



Photograph 15

CNG Post Fire - Dodge Ram



Photograph 16

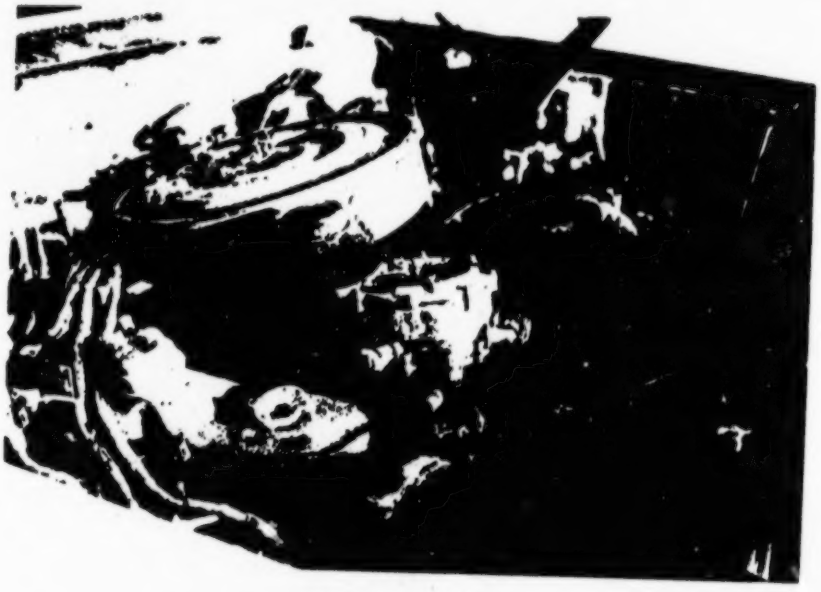
CNG Post Fire - Dodge Ram

Photograph 17

CNG Post Fire - Dodge Ram
(lower portion of regulator melted away)

Photograph 18

Propane, Post Fire - Dodge Ram
(release valve, 2nd from right, melted out)



Photograph 19

Propane, Post Fire - Dodge Ram

10. DISCUSSION

The results of this test program apply specifically to the vehicles tested. As well, because the CNG and LPG powered vehicles in the test were aftermarket conversions, they should not be considered to be representative of an OEM-engineered product. Areas such as tank location and engine tuning could differ radically in a OEM product.

11. CONCLUSIONS

a. Performance and Driveability

In most cases, the gasoline powered vehicles outperformed the propane powered vehicles which in turn outperformed the compressed natural gas powered vehicles. It must be kept in mind that these vehicles were aftermarket conversions and hence do not reflect what may be possible in an OEM product. Also, the CNG powered vehicles were dual fuel systems (switch selectable between CNG and gasoline) and hence engine settings were a compromise between the requirements of the two fuels.

b. Cold Starts

Due to the limited scope of the testing, no generalizations can be made. However, the results indicate that differences do exist and some potential problems, especially in Canadian climatic conditions, may exist.

c. Relative Safety of Refuelling

If proper procedures are developed and adhered to, then none of the fuels are judged to be significantly more dangerous during refuelling.

d. Crash Tests

In a rear end collision, the fuel systems of the propane vehicles tested were more vulnerable to damage due to the location of their tanks. Results of course would be different for collisions in other locations. Again, it should be pointed out that these vehicles are aftermarket conversions and tank location would be different in OEM products.

Fire Tests

Although the propane powered vehicle burned at higher temperatures than the other two vehicles tested, no explosions occurred. In terms of relative safety, no significant differences could be made between the three vehicles.

APPENDIX A

Emission Test Results

ENVIRONMENT CANADA
MOBILE SOURCES DIVISION
VEHICLE TESTING SECTION

DATE: 81/12/ 3 TIME: 12:52: 0

TEST RESULTS SUMMARY

VALID TESTS ONLY

ETL # 100- 16 1981 CHEVROLET IMPALA FND-97A (GASCAINZ)

TEST DATE	PRO	ODOMETRE KM	HC (G/M)	CO (G/M)	NOX (G/M)	CO2 (G/M)	TYPE OF TEST	F C	LAB #	COASTDO
81/11/18	7	4190 9	0 21	3.0 2 28		339	HWFET	9 1	1	16 0
81/11/19	7	4213 3	0 88	13 1 2 23		494	UDDS	13.7	1	0 0
81/11/19	7	4229 3	0 10	1 7 2 33		332	HWFET	8 9	1	16 3
AVERAGE DUE MISC			0 40	5 9 2 28		388		10 6		(3)
AVERAGE HWFET			0 15	2 4	2.30	336		9 0		(2)
AVERAGE UDDS			0 88	13 1	2 23	494		13 7		(1)
AVERAGE LAB 1			0 40	5 9	2 28	388		10 6		(3)

THERE ARE 3 TESTS

ENVIRONMENT CANADA
MOBILE SOURCES DIVISION
VEHICLE TESTING SECTION

DATE: 81/12/ 3 TIME: 12:47:26

TEST RESULTS SUMMARY

VALID TESTS ONLY

ETL # 100- 12 1981 CHEVROLET IMPALA FDD-974 (C_3H_8)

TEST DATE	PRO	ODOMETRE KM	HC (G/M)	CO (G/M)	NOX (G/M)	CO2 (G/M)	TYPE OF TEST	F	C	LAB #	COASTDN
81/11/18	7	4237 8	0 60	1 6	3 48	442	UDDS	15	8	1	0 00
81/11/18	7	4253 9	0 17	0 1	3 78	324	HWFET	11	5	1	16 31
81/11/19	7	4275 4	0 60	1 3	3 55	448	UDDS	16	0	1	0 00
81/11/19	7	4291 5	0 17	0 0	3 66	324	HWFET	11	5	1	16 41
AVERAGE CDE MISC			0 39	0 7	3 62	384		13	7		(4)
AVERAGE HWFET			0 17	0 0	3 72	324		11	5		(2)
AVERAGE UDDS			0 60	1 4	3 52	445		15	9		(2)
AVERAGE LAB 1			0 39	0 7	3 62	384		13	7		(4)

THERE ARE 4 TESTS

ENVIRONMENT CANADA
MOBILE SOURCES DIVISION
VEHICLE TESTING SECTION

DATE: 81/12/ 3 TIME: 12:55:40

TEST RESULTS SUMMARY

VALID TESTS ONLY

ETL # 100- 26 81 CHEVROLET IMPALA FDD-975 1: (CH4)

TEST DATE	PRO	ODOMETRE KM	HC (G/M)	CO (G/M)	NOX (G/M)	CO2 (G/M)	TYPE OF TEST	F C	LAB #	COASTDN
81/11/28	7	3891 2	6 63	66 6	0 51	378	UDDS	27 3	1	0 00
81/11/28	7	3907 4	1 81	34 7	0 35	255	HWFET	17 1	1	14 99
81/11/30	7	3946 1	2 88	45 9	0 69	383	UDDS	25 3	1	0 00
81/11/30	7	3962 0	1 18	24 5	0 59	246	HWFET	15 7	1	15 38
AVERAGE UDE MISC			3 12	42 9	0 54	315		21 4		(4)
AVERAGE HWFET			1 49	29 6	0 47	250		16 4		(2)
AVERAGE UDDS			4 76	56 2	0 60	380		26 3		(2)
AVERAGE LAB 1			3 12	42 9	0 54	315		21 4		(4)

THERE ARE 4 TESTS

ENVIRONMENT CANADA
MOBILE SOURCES DIVISION
VEHICLE TESTING SECTION

DATE: 81/12/ 3 TIME: 12:52:53

TEST RESULTS SUMMARY

VALID TESTS ONLY

ETL # 100- 17 1984 DODGE RAM TRUCK F03-200 (GASOLINE)

TEST DATE	PRO	ODOMETRE KM	HC (G/M)	CO (G/M)	NOX (G/M)	CO2 (G/M)	TYPE OF TEST	F	C	LAB #	COASTDN
81/11/21	7	4225 2	2 38	12 3	2 40	592	UDDS	16	4	2	0 00
81/11/21	7	4240 7	1 70	2 7	3 21	440	HWFET	11	9	2	10 17
81/11/23	7	4282 5	2 28	7 3	2 19	572	UDDS	15	7	2	0 00
81/11/23	7	4298 0	1 74	2 8	3 46	439	HWFET	11	9	2	10 44
AVERAGE OF MISC			2 03	6 3	2 82	511		14	0		(4)
AVERAGE HWFET			1 72	2 7	3 33	439		11	9		(2)
AVERAGE UDDS			2 33	9 8	2 30	582		16	0		(2)
AVERAGE LAB 2			2 03	6 3	2 82	511		14	0		(4)

THERE ARE 4 TESTS

ENVIRONMENT CANADA
MOBILE SOURCES DIVISION
VEHICLE TESTING SECTION

DATE: 81/12/ 8 TIME: 12:48:24

TEST RESULTS SUMMARY

VALID TESTS ONLY

ETL # 100- 13 81 DODGE RAM TRUCK HY2-729 P (C3/4L)

TEST DATE	PRO	ODOMETRE KM	HC (G/M)	CO (G/M)	NOX (G/M)	CO2 (G/M)	TYPE OF TEST	F C	LAB #	COASTDN
81/11/21	7	4244.9	1.04	1.8	1.73	531	UDDS	19.0	2	0.00
81/11/21	7	4260.9	0.64	1.5	2.33	393	HWFET	14.1	2	10.12
81/11/23	7	4305.4	1.05	1.7	1.56	526	UDDS	18.9	2	0.00
81/11/23	7	4321.6	0.60	1.5	2.44	397	HWFET	14.2	2	10.21
AVERAGE OF MISC			0.83	1.6	2.01	462		16.6		(4)
AVERAGE HWFET			0.62	1.5	2.38	395		14.2		(2)
AVERAGE UDDS			1.04	1.8	1.64	528		18.9		(2)
AVERAGE LAB 2			0.83	1.6	2.01	462		16.6		(4)

THERE ARE 4 TESTS

ENVIRONMENT CANADA
MOBILE SOURCES DIVISION
VEHICLE TESTING SECTION

DATE 81/12/ 3 TIME 12 53 47

TEST RESULTS SUMMARY

VALID TESTS ONLY

ETL # 100- 24 1981 DODGE D-150 P/U FD8-199 C (CH4)

TEST DATE	PRO	ODOMETRE KM	HC (G/M)	CO (G/M)	NOX (G/M)	CO2 (G/M)	TYPE OF TEST	F C	LAB #	COASTDN
81/11/27	7	3929 4	9 32	51 1	1 48	517	UDDS	34 0	2	0 00
81/11/27	7	3945 5	0 64	20 4	1 81	376	HWFET	22 4	2	10 58
81/11/28	7	3968 4	2 64	39 8	1 47	500	UDDS	31 1	2	0 00
81/11/28	7	3984 4	0 67	19 9	1 86	362	HWFET	21 6	2	10 47
81/11/30	7	4008 7	3 96	13 0	1 28	417	UDDS	17 2	2	0 00
AVERAGE DOF MISC			3 45	28 8	1 62	474		25 3		(5)
AVERAGE HWFET			0 65	20 1	1 83	369		22 0		(2)
AVERAGE UDDS			5 31	34 6	1 48	544		27 4		(3)
AVERAGE LAB 2			3 45	28 8	1 62	474		25 3		(5)

THERE ARE 5 TESTS

ENVIRONMENT CANADA
MOBILE SOURCES DIVISION
VEHICLE TESTING SECTION

DATE 81/12/ .

TIME 12:45:44

TEST RESULTS SUMMARY

VALID TESTS ONLY

ETL # 100- 11 1981 FORD ECONOLINE HY-27330 (GASOLINE)

TEST DATE	PRO	ODOMETRE KM	HC (G/M)	CO (G/M)	NOX (G/M)	CO2 (G/M)	TYPE OF TEST	F C	LAB #	COASTDN
81/11/18	7	4148 1	0 60	6 8	1 48	688	UDDS	18 6	1	0 00
81/11/18	7	4164 4	0 19	1 0	2 29	513	HWFET	13 7	1	11 91
81/11/21	7	4197 6	0 65	8 8	1 25	656	UDDS	17 8	2	0 00
81/11/21	7	4213 9	0 29	2 0	1 70	488	HWFET	13 1	2	11 89
81/11/23	7	4250 1	0 71	8 4	1 33	638	UDDS	17 3	2	0 00
81/11/23	7	4266 1	0 19	0 6	1 81	473	HWFET	12 6	2	12 08
AVERAGE DDE MISC			0 44	4 6	1 64	576		15 5		(6)
AVERAGE HWFET			0 22	1 2	1 93	491		13 1		(3)
AVERAGE UDDS			0 66	8 0	1 36	661		17 9		(3)
AVERAGE LAB 1			0 40	3 9	1 88	601		14 1		(2)
AVERAGE LAB 2			0 46	4 9	1 52	564		15 2		(4)

THERE ARE 6 TESTS

ENVIRONMENT CANADA
MOBILE SOURCES DIVISION
VEHICLE TESTING SECTION

DATE: 81/12/ 9 TIME: 12:50:34

TEST RESULTS SUMMARY

VALID TESTS ONLY

ETL # 100- 15 1981 FORD ECONOLINE HV-2731 (C3H8)

TEST DATE	PRO	ODOMETRE KM	HC (G/M)	CO (G/M)	NOX (G/M)	CO2 (G/M)	TYPE OF TEST	F C	LAB #	COASTDN
81/11/18	7	4175 1	1 17	16 5	5 64	544	UDDS	20 3	1	0 00
81/11/18	7	4191 3	0 41	7 9	5 83	464	HWFET	16 9	1	11 60
81/11/21	7	4223 8	0 98	10 8	4 08	527	UDDS	19 4	2	0 00
81/11/21	7	4240 0	0 43	5 9	3 48	450	HWFET	16 3	2	11 34
81/11/23	7	4276 3	1 05	12 7	3 90	519	UDDS	19 2	2	0 00
81/11/23	7	4292 3	0 43	8 7	3 76	439	HWFET	16 1	2	11 62
AVERAGE UDF MISC			0 75	10 4	4 45	490		18 1		(6)
AVERAGE HWFET			0 42	7 5	4 36	451		16.5		(3)
AVERAGE UDDS			1 07	13 3	4 54	530		19 7		(3)
AVERAGE LAB 1			0 79	12.2	5 74	504		18 6		(2)
AVERAGE LAB 2			0 72	9 5	3 81	484		17 8		(4)

THERE ARE 6 TESTS

ENVIRONMENT CANADA
MOBILE SOURCES DIVISION
VEHICLE TESTING SECTION

DATE: 81/12/ 3 TIME: 12:5A:

TEST RESULTS SUMMARY

VALID TESTS ONLY

ETL # 100- 27 1981 FORD ECONOLINE HY2-732 C (CH4)

TEST DATE	PRO	ODOMETRE KM	HC (G/M)	CO (G/M)	NOX (G/M)	CO2 (G/M)	TYPE OF TEST	F C	LAB #	COASTDN
81/11/27	7	3875 9	7 72	4 7	0 92	515	UDDS	29 7	2	0 00
81/11/28	7	3915 1	3 02	1 7	0 67	473	UDDS	26 4	2	0 00
81/11/28	7	3931 0	1 65	0 2	0 87	387	HWFET	21 4	2	11 60
81/11/28	7	3893 0	1 81	0 2	0 90	396	HWFET	21 9	2	11 49
81/11/30	7	3955 9	0 83	8 1	1 45	630	UDDS	17 1	2	0 00
81/11/30	7	3975 5	0 33	2 9	1 69	484	HWFET	13 0	2	11 28
AVERAGE DOF MISC			2 59	3 0	1 08	481		21 6		(6)
AVERAGE HWFET			1 33	1 1	1 15	422		18 8		(3)
AVERAGE UDDS			3 86	4 8	1 02	539		24 4		(3)
AVERAGE LAB 2			2 59	3 0	1 08	481		21 6		(6)

THERE ARE 6 TESTS

ENVIRONMENT CANADA
MOBILE SOURCES DIVISION
VEHICLE TESTING SECTION

DATE: 81/12/ ? TIME: 12:49:31.

TEST RESULTS SUMMARY

VALID TESTS ONLY

ETL # 100- 14 1981 OLDSMOBILE OMEGA FND-979 (GASOLINE)

TEST DATE	PRO	ODOMETRE KM	HC (G/M)	CO (G/M)	NOX (G/M)	CO2 (G/M)	TYPE OF TEST	F C	LAB #	DEGRADATION
81/11/19	7	4157 1	0 69	17 3	0 52	487	UDDS	13 7	2	0 00
81/11/19	7	4173 9	0 11	0 3	0 88	316	HWFET	8 4	2	14 85
81/11/30	7	4217 1	0 70	16 1	0 54	499	UDDS	14 0	1	0 00
81/11/30	7	4233 7	0 11	0 2	0 98	315	HWFET	8 4	1	15 55
81/12/ 1	7	4255 3	0 71	9 3	1 16	469	2BAG HOT	12 9	1	0 00
81/12/ 1	7	4281 4	0 12	0 1	0 90	305	HWFET	8 1	1	15 46
AVERAGE DOE MISC			0 41	7 2	0 83	398		10 9		(6)
AVERAGE HWFET			0 11	0 2	0 92	312		8 3✓		(3)
AVERAGE 2BAG HOT			0 71	9 3	1 16	469		12 9		(1)
AVERAGE UDDS			0 69	16 7	0 53	493		13 8✓		(2)
AVERAGE LAB 1			0 41	6 4	0 90	397		10 8		(4)
AVERAGE LAB 2			0 40	8 8	0 70	401		11 0		(2)

THERE ARE 6 TESTS

ENVIRONMENT CANADA
MOBILE SOURCES DIVISION
VEHICLE TESTING SECTION

DATE 81/12/ ? TIME 12:44:34

TEST RESULTS SUMMARY

VALID TESTS ONLY

ETL # 100- 10 1981 OLDSMOBILE OMEGA FDD-977 (C_3H_8)

TEST DATE	PRO	ODOMETRE KM	HC (G/M)	CO (G/M)	NOx (G/M)	CO2 (G/M)	TYPE OF TEST	F C	LAB #	COASTDN
81/11/30	7	4192.2	0.68	1.04	81	358	UDDS	12.8	1	0.00
81/11/30	7	4208.9	0.19	0.04	.97	255	HWFET	9.1	1	15.07
81/12/ 1	7	4229.5	0.71	1.05	.13	357	UDDS	12.8	1	0.00
81/12/ 1	7	4246.3	0.18	0.05	.24	259	HWFET	9.2	1	15.01
AVERAGE DOE MISC			0.44	0.55	.04	307		11.0		(4)
AVERAGE HWFET			0.18	0.05	.10	257		9.1		(2)
AVERAGE UDDS			0.70	1.04	.97	358		12.8		(2)
AVERAGE LAB 1			0.44	0.55	.04	307		11.0		(4)

THERE ARE 4 TESTS

ENVIRONMENT CANADA
MOBILE SOURCES DIVISION
VEHICLE TESTING SECTION

DATE 81/12/ 3 TIME 12:54:44

TEST RESULTS SUMMARY

VALID TESTS ONLY

ETI # 100-25 .. 81 OLDSMOBILE OMEGA FOD-978 C (Cdy)

TEST DATE	PRO	ODOMETRE KM	HC (G/M)	CO (G/M)	NOX (G/M)	CO2 (G/M)	TYPE OF TEST	F C	LAB #	COASTDN
81/11/30	7	3893 8	1 28	1 2	1 20	337	UDDS	18 7	1	0 00
81/11/30	7	3910 6	0 75	-0 0	1 31	225	HWFET	12 4	1	15 36
81/12/ 1	7	3925 9	0 73	0 0	1 27	224	HWFET	12 4	1	14 97
81/12/ 2	7	3957 6	1 23	0 1	1 30	323	UDDS	17 8	1	14 98
AVERAGE ONE MISC			1 00	0 3	1 27	277		15 3		(4)
AVERAGE HWFET			0 74	0 0	1 29	224		12 4		(2)
AVERAGE UDDS			1 26	0 6	1 25	330		18 3		(2)
AVERAGE LAB 1			1 00	0 3	1 27	277		15 3		(4)

THERE ARE 4 TESTS

APPENDIX B

Driveability Rating System

DRIVEABILITY CYCLE

Step 0 a) Start engine according to manufacturer's recommendations.

Step 0 b) Idle in neutral at fast idle for 10 seconds.

Step 0 c) Idle in neutral at reduced rmp for 10 seconds.

Step 0 d) Idle in gear for 10 seconds.

Step 1 Part throttle acceleration to 10 mph, 0.1 km cruise at that speed, deceleration to a full stop, let idle in gear for 5 seconds.

Step 2 Full throttle acceleration to 20 mph, 0.1 km cruise at that speed, deceleration to a full stop, let idle in gear for 5 seconds.

Step 3 Part throttle acceleration to 20 mph, 0.1 km cruise at that speed, full throttle acceleration to 30 mph, 0.1 km cruise at that speed, deceleration to a full stop, let idle in gear for 5 seconds.

Step 4 Repeat Step 3.

Step 5 Repeat Step 3.

Step 6 Repeat Step 3.

Step 7 Repeat Step 3.

Step 8 Repeat Step 3.

Step 9 Repeat Step 3.

Step 10 Part throttle acceleration to 20 mph, 0.1 km cruise at that speed, full throttle acceleration to 30 mph, 0.1 km cruise at that speed, deceleration to a full stop, turn engine off for 10 seconds and restart.

Step 11 Repeat Step 3.

Step 12 Repeat Step 3.

Step 13 Repeat Step 3.

Step 14 Repeat Step 3.

Step 15 Repeat Step 10.

Step 16 Repeat Step 3.

Step 17 Repeat Step 3.

Step 18 Repeat Step 3.

Step 19 Repeat Step 3.

Step 20 Repeat Step 3.

START RATING

START TIME (SEC)	ALL STARTS (EXCEPT COLD STARTS BELOW -8°C)	COLD STARTS (BETWEEN -8°C & -18°C)	COLD STARTS (BETWEEN -18°C & -30°C)
1.0 or less	9	9	9
1.1 to 2.0	8	9	9
2.1 to 3.0	7	8	9
3.1 to 4.0	6	8	8
4.1 to 5.0	5	7	8
5.1 to 6.0	4	6	7
6.1 to 7.0	3	5	7
7.1 to 8.0	2	5	6
8.1 to 9.0	2	4	5
9.1 to 10.0	1	3	5
10.1 to 12.0	0	2	4
12.1 to 14.0	0	1	3
14.1 to 15.0	0	0	1
over 15.0	0	0	0

STALL RATING

STALLS (OVERALL FOR TEST)	ALL STARTS (EXCEPT COLD STARTS BELOW -8°C)	COLD STARTS (BETWEEN -8°C & -18°C)	COLD STARTS (BETWEEN -18°C & -30°C)
none	7	7	7
1	5	6	6
2	2	4	5
3	1	2	4
4 or more	0	0	2

IDLE RATING

DESCRIPTION	RATING
Driver can not feel that engine is running	9
Engine running is barely perceptable, idle is totally smooth & flawless	8
Engine vibration is noticeable but smooth & unobjectionable	7
Consistent idle speed with slight engine roughness	6
Irritating condition (moderately rough or pulsating idle)	5
Disturbing driver still has confidence that the vehicle will continue to run, may cause severe driveline shock upon engagement or is very rough	4
Driver is not confident in vehicle's ability to perform reliably	3
frequent die-outs	2
Multiple die-outs, erratic and uncontrollable operation	1

DRIVE RATING

_9_ exceptionally good responsive feel under all conditions

_8_ traces of undesirable elements found with extreme concentration

_7_ one or more undesirable characteristics found, but with no concentration

_6_ definitely noticeable undesirable characteristics but not objectionable

_5_ obvious and somewhat irritating undesirable characteristics

_4_ disturbing but driver still confident in vehicle's ability to continue running

_3_ driver is not confident in vehicle's ability to perform reliably

_2_ failure of engine to continue running

_1_ condition that could cause unpredictable driveability

APPENDIX C

Conversion Components

CONVERSIONS

Propane conversions were performed by

ICG Auto Propane
112 Baslatic Road
P.O. Box 670
Maple, Ontario

Major components used in the conversions are listed in Table 1c. Tank locations for the four vehicles are shown in Figures 1c to 4c. The four vehicles were converted to run on propane only and the OEM gasoline tanks were removed. Labour costs for installation are estimated to be about $200.

Compressed Natural Gas conversions were performed by

CNG Fuel Systems
Suite 422
435 4th Ave. S.W.
Calgary, Alberta

Major components used in the conversions are listed in Table 2c. Tank locations for the four vehicles are shown in Figures 5c to 8c. The four vehicles were converted to run on either compressed natural gas or gasoline. Fuel selection was done with a dash mounted switch. Labour costs for installation are estimated to be about $200.

TABLE 1c

PROPANE CONVERSION COMPONENTS

	TANKS			REGULATOR	VACUUM FUEL LOCK	CARBURETOR	IGNITION	COST OF PARTS ($)
	No.	Size	Manufacturer					
Chevrolet Impala	1	14"Ø x 45" L	Brunner	Impco model E	Impco model VFF30	Impco model 225	lock-up plate	1388
Dodge Ram	1	20"Ø x 64" L	Brunner	Impco model E	Impco model VFF30	Impco model 225	lock-up plate and alter spring	1407
Ford Econoline	2	12"Ø x 36" L	Glitche	Impco model E	Impco model VFF30	Impco model 225	alter spring	1211
Oldsmobile Omega	1	13"Ø x 44" L	Brunner	Impco model E	Impco Model VFF30	Impco model 225	lock-up plate	1383

TABLE 2c

CNG CONVERSION COMPONENTS

	TANKS			REGULATOR	VACUUM FUEL LOCK	INJECTOR BODY	IGNITION	COST OF PARTS ($)
	No.	Size (L)	Manufacturer					
Chevrolet Impala	2	50	Faber	Renzo Landi	part of regulator	CNG Fuel Systems	Autotronics Controls Corp dual curve	1220
Dodge Ram	2	50	Faber	Renzo Landi	part of regulator	CNG Fuel Systems	Autotronics Controls Corp dual curve	1220
Ford Econoline	2	50	Faber	Renzo Landi	part of regulator	CNG Fuel Systems	Autotronics Controls Corp dual curve	1220
Oldsmobile Omega	1	50	Faber	Renzo Landi	part of regulator	CNG Fuel Systems	Autotronics Control Corp dual curve	1220

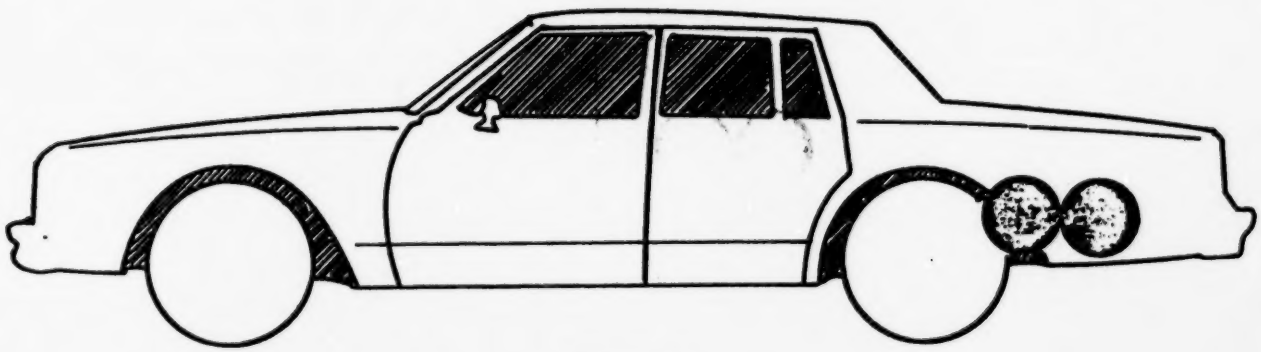


FIGURE 1C

CNG Tank Location - Chevrolet Impala

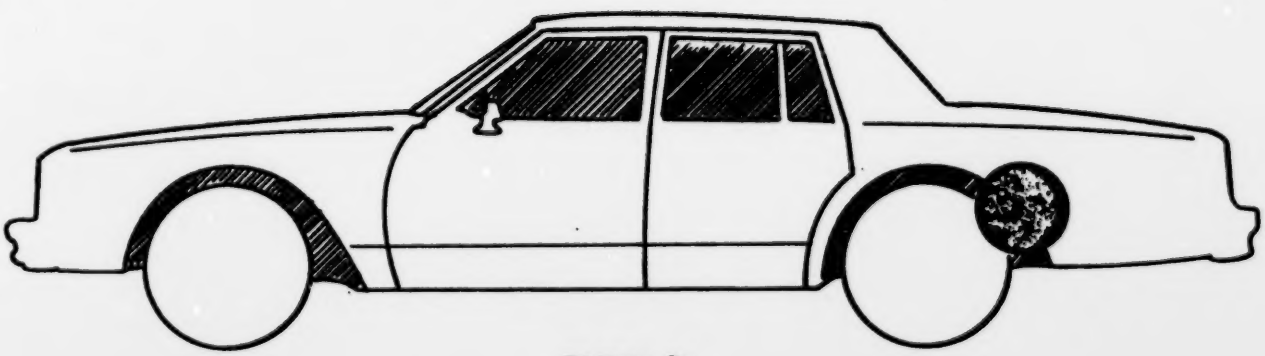


FIGURE 2C

Propane Tank Location - Chevrolet Impala

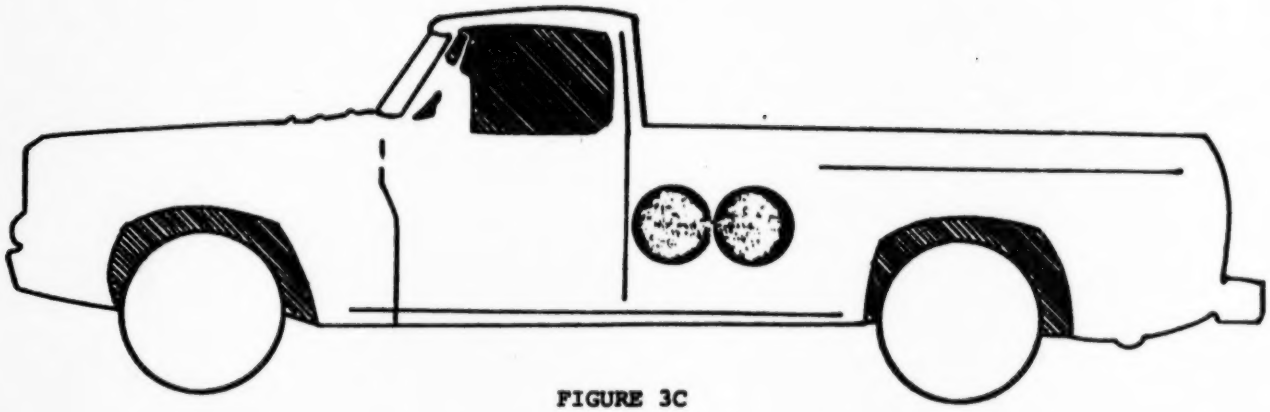


FIGURE 3C

CNG Tank Location - Dodge Ram

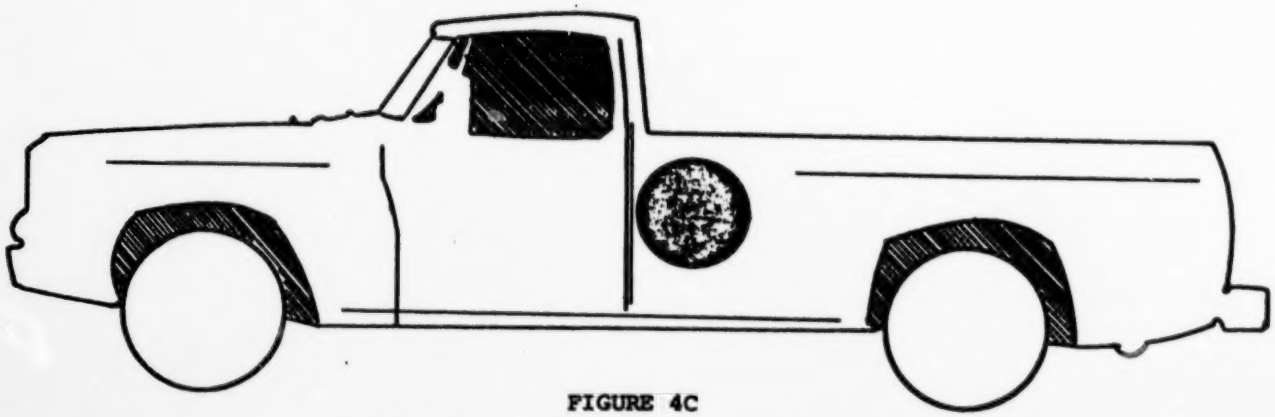


FIGURE 4C

Propane Tank Location - Dodge Ram

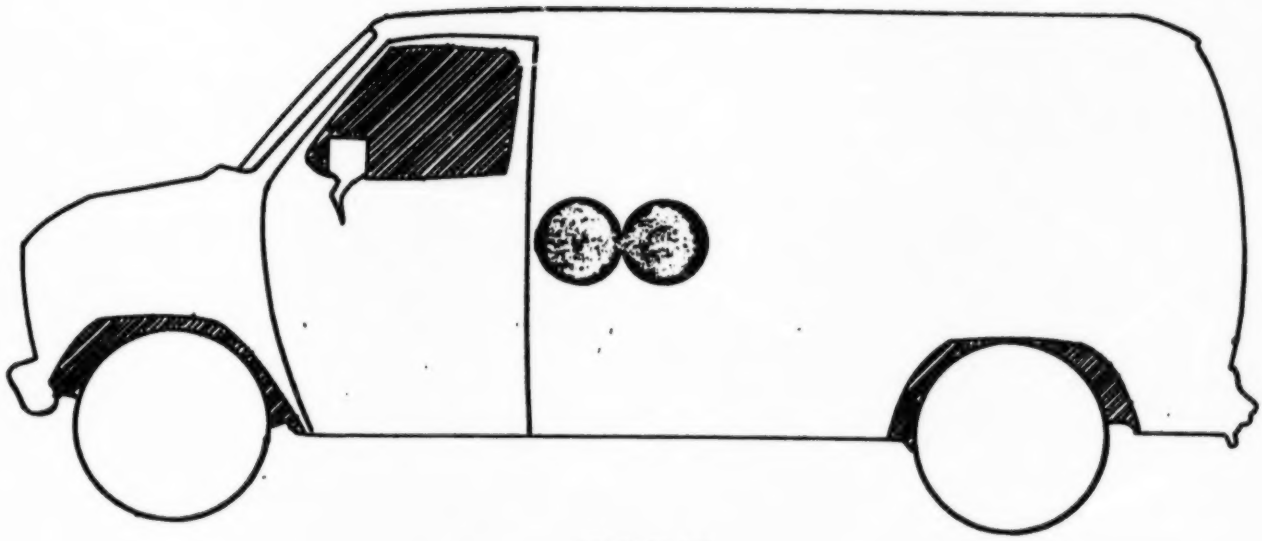


FIGURE 5C

CNG Tank Location - Ford Econoline

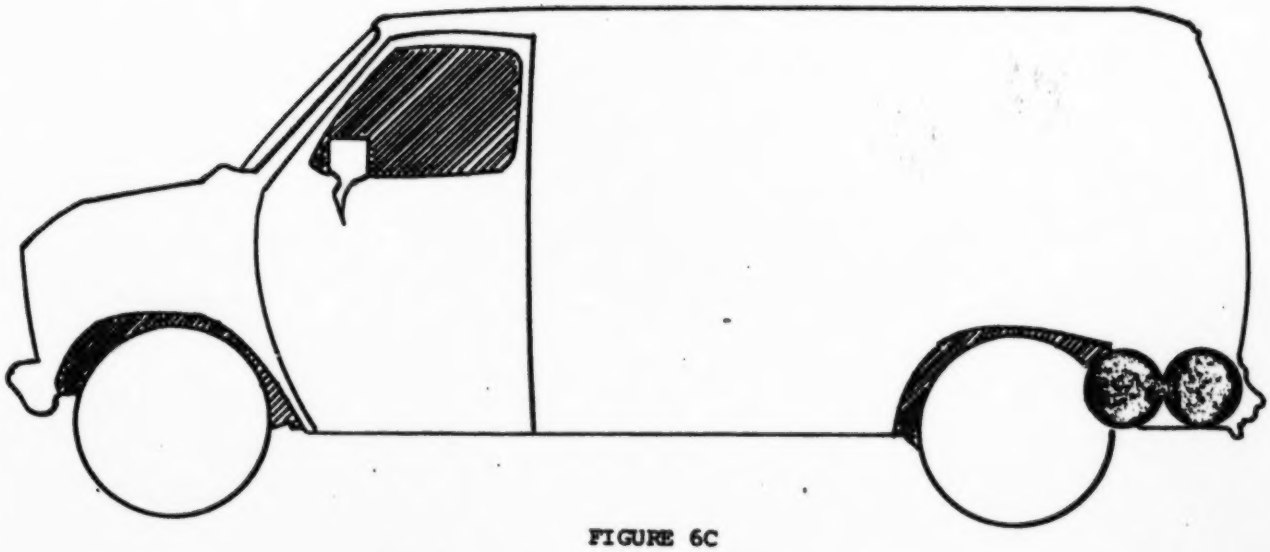


FIGURE 6C

Propane Tank Location - Ford Econoline

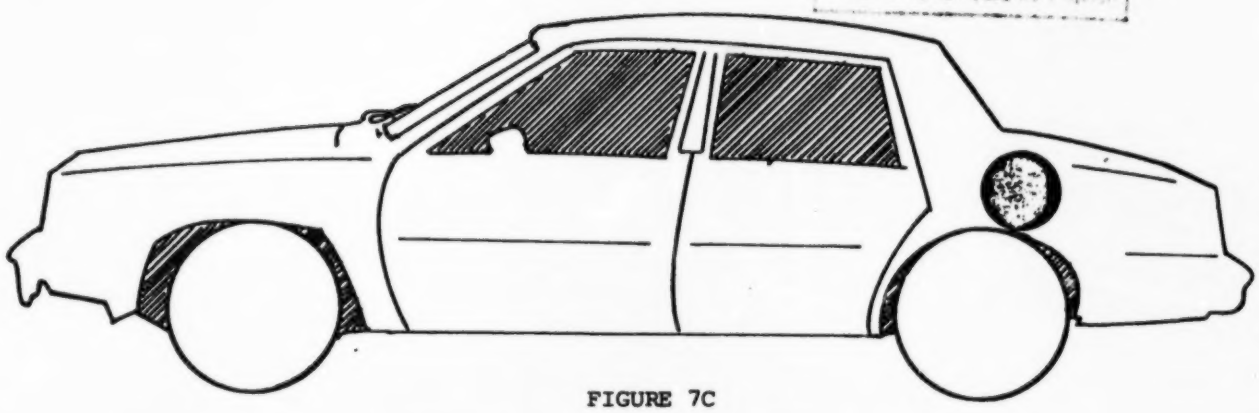


FIGURE 7C

CNG Tank Location - Oldsmobile Omega

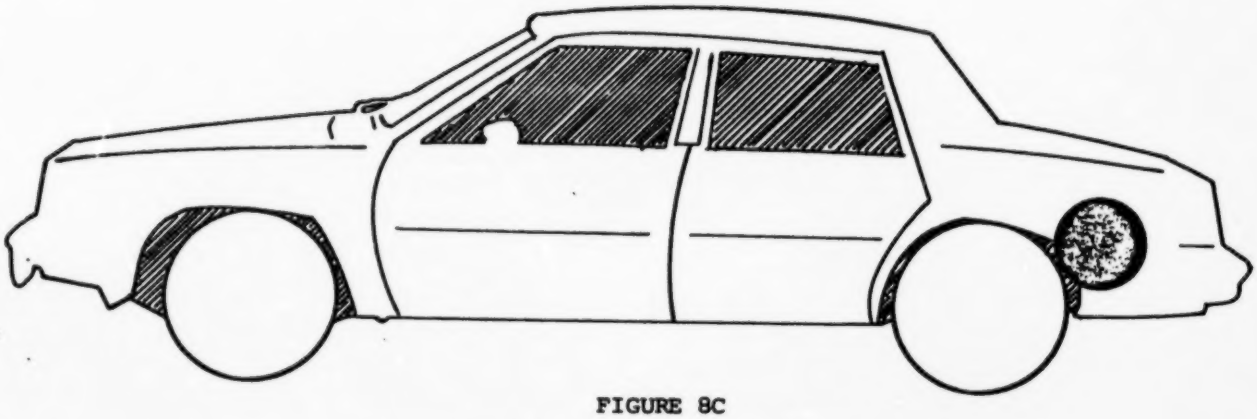


FIGURE 8C

Propane Tank Location - Oldsmobile Omega